APPENDIX B:
IMPACT OF TIMBER HARVESTING ON LANDSLIDE PROCESSES

Timber harvesting (tree removal alone) can potential impact hillslope stability through root strength and altered hillslope hydrology. Root strength is a potential significant factor in the stability of shallow soils on steep slopes. Root systems can provide lateral reinforcement to shallow soils and vertical anchorage of soils to underlying more competent materials, thereby increasing the effective shear strength (Burroughs and Thomas 1977; Gray and Sotir 1996; O'Loughlin and Ziemer 1982; Sidle et al. 1985; Ziemer and Swanston 1977). The effect of root strength generally acts only on the upper 4 to 8 feet of the surface. Loss of root strength through timber harvesting and root die back could potentially contribute to a greater risk of shallow debris slides on steep slopes. Roots generally have little effect on deep-seated stability where the basal slide plane extends substantially deeper than the depth of root penetration (Sidle et al. 1985; Yoshinori and Osamu 1984). The net effect of a reduction in root strength is short term, and diminishes once vegetation is re-established, often within 20 years following the harvest.

The majority of studies have focused on clearcutting in Douglas fir forests with high root die-back, with little research conducted on other silviculture prescriptions, such as partial cuts. Partial cutting that maintains an understory and leaves a viable rooting mass intact after cutting and harvesting of redwood or hardwood forests that generally sprout vigorously after cutting, maintaining a viable root network, would have less impact on slope stability than clear cutting (Krogstad 1995; Schmidt et al. in review; Sidle 1991; Sidle 1992; Ziemer 1981b).

Few studies have been conducted that evaluate the impact of different stand densities on slope stability and shallow landslides. The ODF study of the effects of the 1995-96 storms revealed that comparatively few landslides originated in partially cut areas (Robison et al. 1999). Similarly, little change in landslide rates was documented in partial cuts in the *Draft Freshwater Creek Watershed Analysis* (PALCO, 2001).

When relating landslide occurrence to changes in vegetation crown cover, studies in Idaho revealed that landslide frequency increases only slightly as overstory crown cover is reduced from 100 percent to 11 percent. However, a notable increase in landslides occurs when crown cover is reduced below 11 percent (Megahan et al. 1978). The Idaho study may not be applicable to the north coast area because of differences in geology and vegetation; nonetheless, it illustrates that in some areas, even a rudimentary root network can increase soil stability on a hillside. The relatively low impact that partial cuts have on landslide occurrence is also supported by the preliminary Simpson Timber Company data.

Modeling studies of shallow landslides and the effects of different silvicultural systems on root strength suggest that partial cutting results in substantially greater residual root strength and a substantially lower probability of slope failure compared to a clearcut scenario (Krogstad 1995; Schmidt et al. in review; Sidle 1991; Sidle 1992; Ziemer 1981a; Ziemer 1981b). For example, Sidle (1992) reports "A 75 percent partial cut reduced the maximum probability of failure more than five times compared with clearcut simulation." Ziemer (1981a) suggests that under shelterwood removal silviculture, where 70 percent of the original stand is harvested followed by removal of the remaining trees 10 years later, root reinforcement dropped to about 70 percent of its uncut value at 2 to 3 years post harvest, then rose to about 10 percent above the uncut value after about 7 years after harvest as the residual trees quickly expand. About 15 years after the residual trees were harvested, root reinforcement again dropped to about 50 percent of the uncut value. Under a light selection harvest where 20 percent of the trees were cut every 10 years, root strength would decrease by about 3 percent 2 years after harvest, then increase to about 7 percent above the uncut strength as a result of rapid expansion of the roots of the remaining trees. It is important to recognize that the foregoing modeling results are for maximum short-term impact. Long-term impact over complete rotations (i.e., 50 years) would be substantially less.

Modeling studies have also shown that understory vegetation often represents an important component of total root cohesion and that the retention of the understory canopy can substantially reduce the probability of slope failure (Schmidt et al, in review, Krogstad, 1995, Sidle, 1992). Because shallow landslides might opportunistically exploit gaps in the root network when partial harvesting is employed, uniform spacing of trees to minimize "gaps" that might develop in the root network between trees is important to provide the greatest root strength benefit (Burroughs and Thomas 1977; Schmidt et al. in review).

Evapotranspiration influences soil water recharge and subsurface flow and thus has the potential for affecting slope stability. The removal of vegetation from a hillside may locally increase the level of ground saturation by reducing the amount of water transpired through the canopy. This could contribute to a greater risk of shallow and deep-seated instability in areas that are sensitive to groundwater changes. Shallow landslides, however, are typically triggered by high groundwater levels during high intensity rainfall events in the winter months when vegetative transpiration rates are already low. Once antecedent moisture conditions are met, generally by early December, the difference in soil moisture between logged (clear-cut) and unlogged slopes is virtually indistinguishable (Gray 1977). On the other hand, reduced evapotranspiration may allow near surface soils to stay wetter longer and therefore exposing the slope to a potential triggering storm event for a longer period of time. Moreover, reduced canopy interception may allow a greater volume of rainfall to reach the ground surface during individual storm events. In general, however, the net effect of reduced evapotranspiration on increased soil moisture and corresponding porewater pressures is probably dependent upon a number of independent factors including regional climate and storm history, and site-specific soil and hydrologic conditions. The impact of an individual timber harvest on porewater pressures is site specific, dependent upon the characteristics of the underlying parent material (hydraulic conductivity, storativity, shear strength, etc), hillslope geometry, water input, and density of the residual stand.

Little work has been done on evaluating the impact of timber harvesting on sediment production from deep-seated landslides, and regional empirical landslide studies have produced varying conclusions. Short-term increases in ground displacement following clear cutting have been documented on several active earthflows in the Coastal and Cascade Ranges of Oregon (Swanson and Swanston 1977). In contrast, work by (Pyles et al. 1987) on the Lookout Creek Earthflow in Northern Oregon concluded that timber harvesting was unlikely to induce a large increase in movement, primarily because the slide was well drained. Modeling of hydrology and slope stability of an episodically active landslide in the western Washington Cascades by Miller and Sias (1998) revealed only small changes in the factor of safety from clearcutting in the landslide groundwater recharge area. Their model showed differential stability in different portions of the landslide, suggesting that in relatively stable areas, the increment of reduced factor of safety was not significant and that in relatively unstable areas, the increment of reduced factor of safety could be significant.

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INVESTIGATIVE LIMITATIONS

1. The purpose of this study was to conduct a limited field and air photo investigation to evaluate the geologic feasibility of the proposed timber harvest plan. This study is focused on *reducing* the potential impact of the proposed THP on slope instability with sediment delivery to fish bearing streams.
2. The interpretations and conclusion presented in this report are based on a study of inherently limited scope. Observations were qualitative limited to surface expressions and limited natural and artificial exposures of subsurface materials at and adjacent to the harvest area. Subsurface sampling, slope stability modeling are beyond the scope of this investigation. Interpretations of problematic hillslopes are typically based on the nature and distribution of existing landslide features. For this reason, the conclusions should be considered limited in extent.
3. Recommendations outlined in this report are based on qualitative observations and are designed to minimize the level of potential risk associated with the identified geologic hazards. Any "engineered" structure identified or recommended in this report should be reviewed by a licensed civil or geotechnical engineer as deemed necessary by the landowner. The conclusions and recommendations noted in this report are based on probability and do not imply the site will not possibly be subjected to rainfall, ground failure or seismic shaking so intense that structures or roads will be severely damaged or destroyed.
4. This written report comprises all our professional opinions, conclusions and recommendations. This report supersedes any previous oral or written communications concerning our opinions, conclusions and recommendations.
5. This report is issued with the understanding that it is the duty and responsibility of the client, or his or her representative or agent, to ensure that the recommendations contained herein are fully implemented.
6. The findings of this report are valid as of the present date. However, changes in the conditions of a property or landform can occur with the passage of time, whether due to natural processes or to the works of man, on this or adjacent properties. In addition, changes in applicable or appropriate standards occur whether they result from legislation or the broadening of knowledge. Accordingly, the findings of this report may be invalidated, wholly or partially, by changes outside my control.

I would like to thank you for this opportunity to assist you in your land use planning. If you have any questions or desire additional clarification, please don't hesitate to contact me.

Sincerely,

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TIMOTHY C. BEST
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CERTIFIED
ENGINEERING
GEOLOGIST
STATE OF CALIFORNIA

Timothy C. Best
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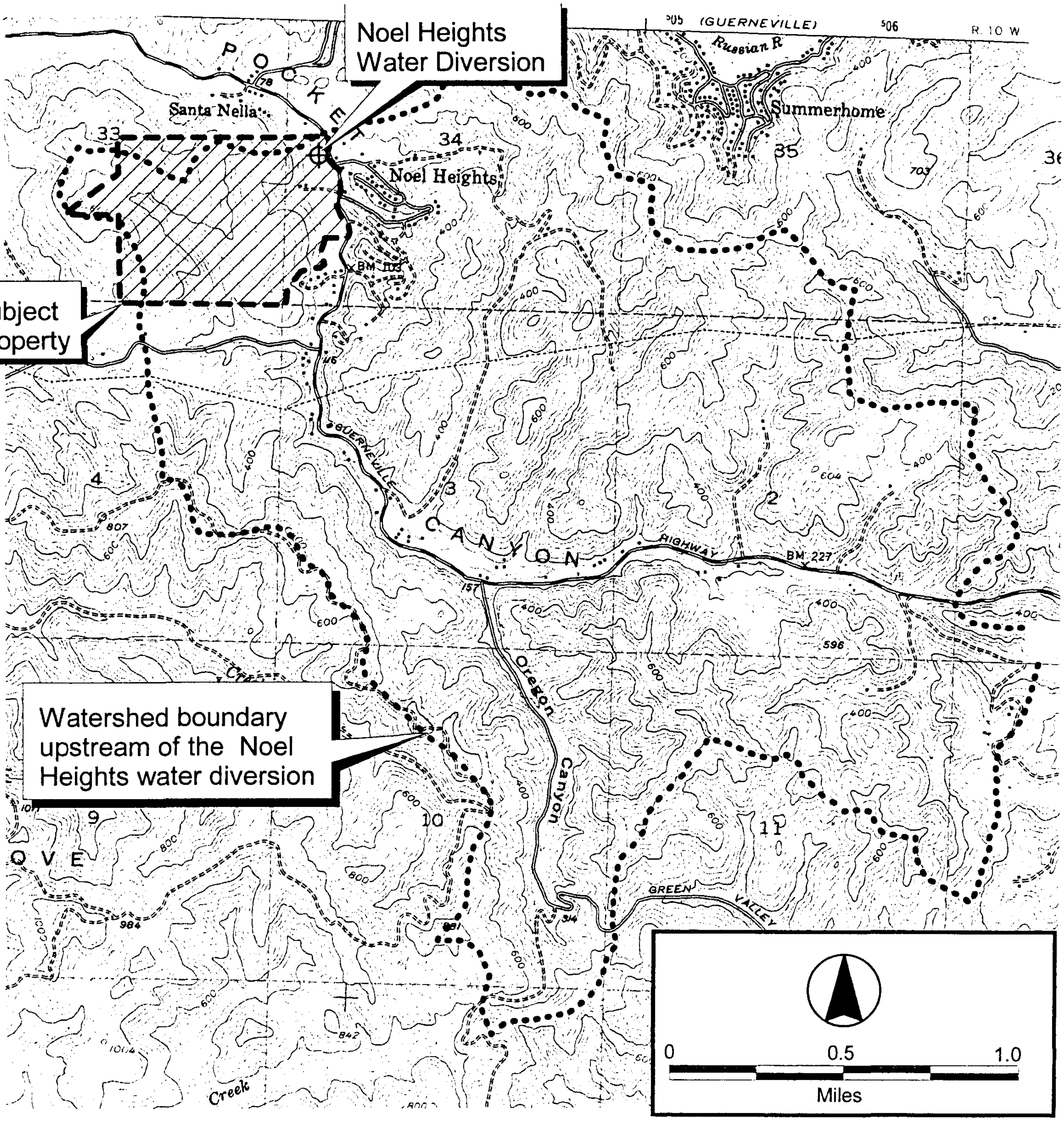
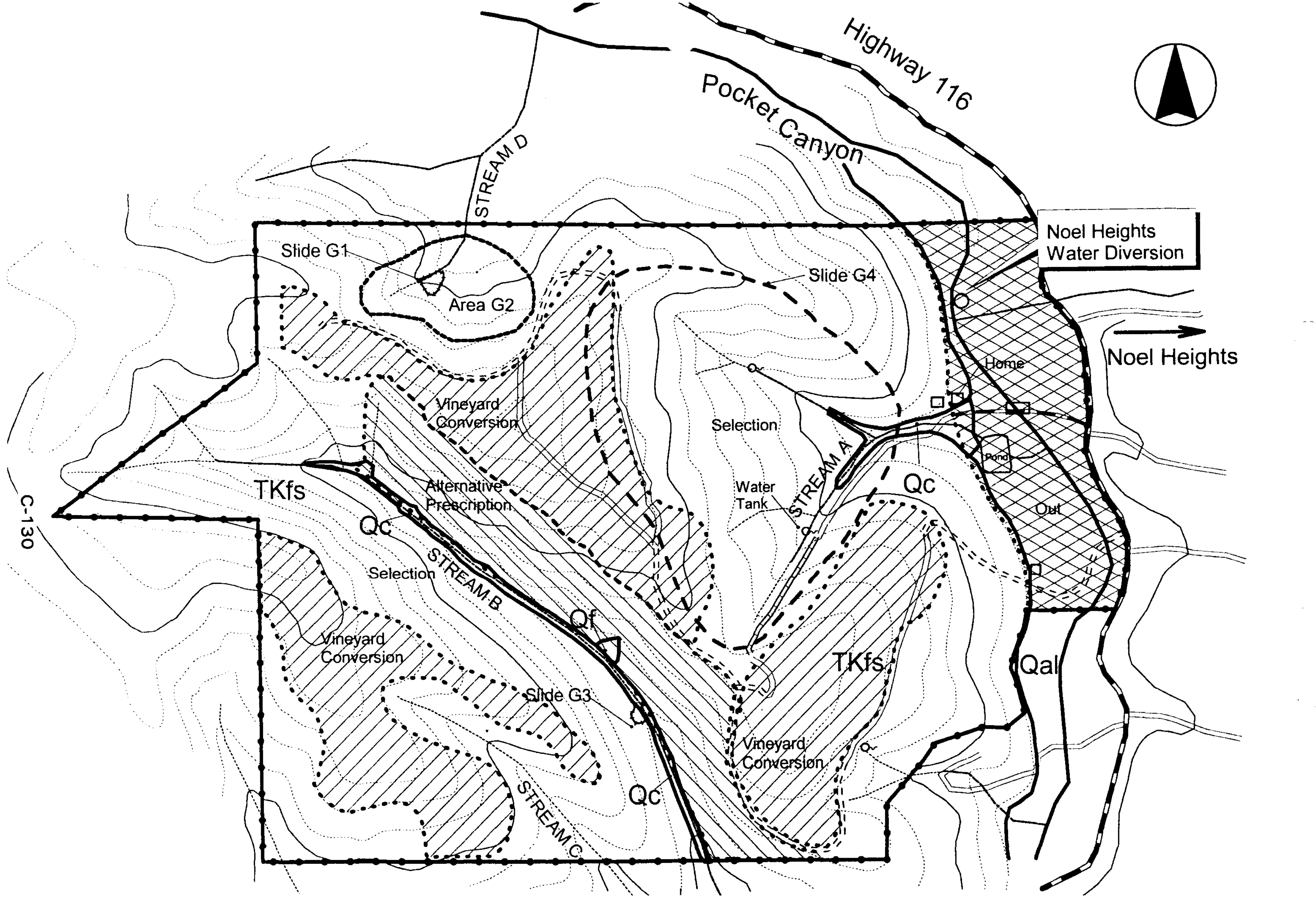


TIMOTHY C. BEST, CEG O'CONNOR ENVIRONMENTAL, INC ENGINEERING GEOLOGY AND HYDROLOGY 1002 Columbia Street, Santa Cruz, CA 95060 (831) 425 5832 (831) 425 5830 (fax)	REGIONAL SITE MAP POCKET CANYON THP Sonoma County, CA	FIGURE 1 Job: JB-POCKET-282 6/30/02



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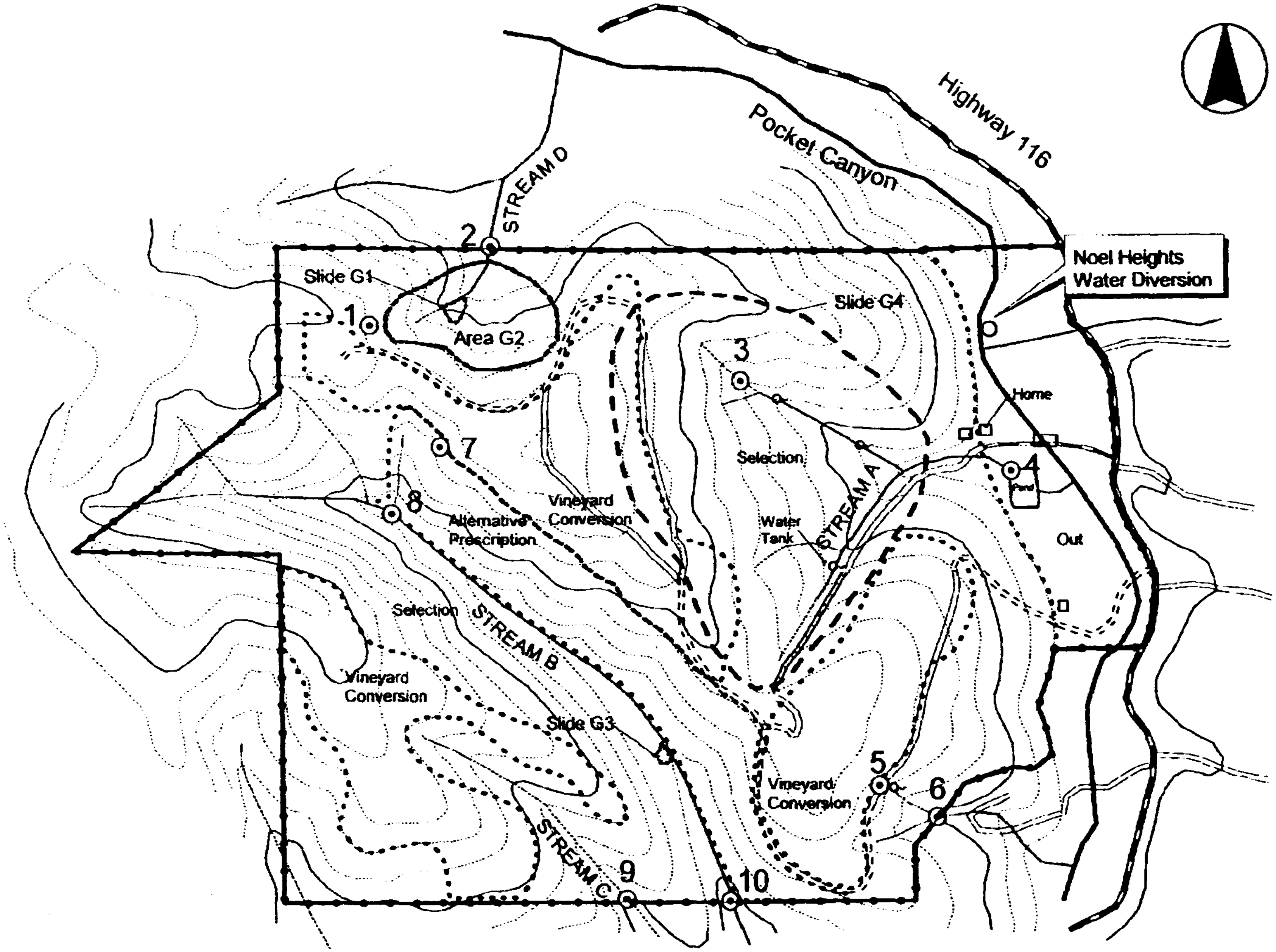
GEOLOGIC AND SILVICULTURE MAP
POCKET CANYON THP
Sonoma County, CA

FIGURE 2

Job: JB-POCKET-282

Sc "=500'



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SUB-WATERSHED RUNOFF NODES
POCKET CANYON THP
Sonoma County, CA

FIGURE 3

Job: JB-POCKET-282

Scale: 1" = 500'

Figures 2 and 3:
LEGEND

SYMBOLS

Geologic contact

Shallow landslide

Mapped deep-seated landslide

This landslide was mapped by Huffman and Armstrong. We found no definitive evidence for the existence of this slide during our field reconnaissance of the slide.

Slope stability area of concern

Watercourse

- Class I
- Class II
- Class III

Spring

Runoff Node

Road

- Paved
- Existing dirt road (proposed to be rocked)
- Proposed rocked road
- Proposed road to be abandoned

Silviculture boundary

- Vineyard conversion
- Alternative Prescription
- Selection
- Out

Property Boundary

Building

EARTH MATERIALS

Qf: **Debris Fan**

Qc: **Colluvium**

Qal: **Alluvium**

Tkfs: **Coastal Belt Franciscan Formation:** Predominately sandstone and shale, locally highly sheared and fractured.